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ABSTRACT

The effects of variation in instructional media design for all learners and for low and high ability learners considered separately are investigated in this paper, and the results are collected into a set of prescriptions for instructional media design. The literature of the aptitude-treatment interaction field is reviewed, and 10 statements on learning are made which are considered generally supported by the research. These are collected into separate lists of factors or variables that disproportionately benefit either high mental ability students or low mental ability students. Those instructional procedures that benefit low ability learners are characterized as largely serving a "compensatory" function, that is, they provide the mediators, organization, and modality that the students cannot provide for themselves. In turn, the instructional procedures that benefit high ability students serve a "preferential" function by calling on and utilizing their higher aptitudes. These generalizations are then expanded to form very detailed prescriptions for instructional media design, depending on the mental ability of the learners. (WH)

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Intellectual Abilities and Instructional Media Design

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This paper has two objectives: first, to determine if interactions exist between the intellectual abilities of learners and the different ways instructional media may be designed and produced; and, second, to translate the findings from this search into prescriptions for the actual development of instructional products.

The accomplishment of these objectives is a difficult task. As has been convincingly pointed out by Bracht (1970) and by Cronbach and Snow (1973), there is little definitive evidence from the aptitude-treatment interaction research that points conclusively to the employment of practices that might guide the selection of the more general instructional strategies, much less to the design of specific instructional media. The research results are so fragmentary and diverse that generalizations from these alone are virtually impossible. Thus, if an application to practice is to be made, we must look beyond the experimental data and base our decisions also on theories about how individuals learn and process

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information and upon the apparent directions suggested by the findings. This may appear to be a shaky foundation for the conclusions that will be drawn, but it is the best we can do at this stage. The risk of over-generalization or over-simplification is a real one, but a risk that may be worth taking if the results lead to deeper insights or new hypotheses that warrant further investigation.

The translation of research and theory into real-life applications is desparately needed. This would appear to be what research in education is all about: to discover procedures and practices that may be applied to the improvement of instruction and the enhancement of learning. Yet, this transfer is so seldom accomplished, either through the inability or hesitation of the researcher or theoretician to interpret his findings so that they may be used or the reluctance of the practitioner to accept these findings or incorporate them into his teaching practices. Thus, the attempt will be made here to bridge the gap between the researcher and the instructional media designer, at least to the extent that the research and theory will be synthesized into a set of prescriptions that have implications for the ways instructional materials may be designed to satisfy the learning requirements of individuals of differing intellectual abilities.

The results cited in this paper and the theoretical constructs that appear come from a number of individual and general sources. The individual studies are referenced when they occur, but special mention should be made of those more general sources of information from which

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conclusions are drawn, both in relation to trait-treatment and to instructional media considerations. The foremost source of knowledge was the preliminary unpublished draft of the forthcoming book of Cronbach and Snow (1973) on aptitudes and instructional methods. Many of the reviews of specific research studies are drawn from this definitive work. The most recent review of trait-treatment interaction research and consideration of the issues involved is the paper by Berliner and Cahen (1973), and Snow and Salomon (1968) and Snow (1970) treat the subject in some depth. The symposium papers on learning and individual differences edited by Gagné (1967) discussed useful facets of the problem, as do Glaser's (1972) and Di Vesta's (1973) more recent papers. The compilations of reseach studies conducted in the Instructional Film Research Program at Pennsylvania State University and compiled by Carpenter (1953) and Carpenter and Greenhill (1956) and the studies of Air Force research edited by Lumsdaine (1961) comprise a considerable body of research on media design techniques. The media research in its entirety is ably reviewed by Lumsdaine (1963), and his paper gives the best concise source of information related to design techniques.

This paper will be limited to a consideration of the general aptitude or trait we classify as "intellectual ability." This term is obviously a catch-all for a large group of traits, and to lump them together and attach this general label is risky. Yet there do appear to be certain abilities of an intellectual nature that are being measured by the most widely employed mental ability tests and which have been given this name. For the most part, these are the tests being reported in the

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aptitude-treatment interaction studies. So the use of this omnibus term "intellectual ability" seems justified, at least in this exploratory investigation of aptitude-media design relationships. However, it should be kept clearly in mind that this analysis groups specific mental abilities together and treats them as if they were representative of some general intellectual ability.

If it can be said that a class of individuals (those we label as of lower mental ability) is deficient in abstract reasoning and in attentional, preceptual coding, perceptual processing, and analytical skills, it might be possible to predict how such learners will respond to instructional material that either demands the application of such skills or compensates for their deficiencies. Similarly, if we can say that another class of individuals (which may be labeled as those with high mental ability) possess these skills, we may, in turn, be able to predict how those learners will respond to different forms of stimulus presentation.

Instructional media design, as considered in this paper, refers specifically to the ways the instructional message is manipulated in the design and production process so as to influence consciously and deliberately the learning from that material. It is assumed that the material produced will be reproducible in the sense that it will possess a unique set of qualities that will persist regardless of the number of times it is used in instruction. These materials have been called "software" of instruction and include such media as printed textual material, motion picture films, filmstrips, recorded audio presentations, videotapes, programed texts, computer-mediated instructional programs, and other organized sequential

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materials that have been recorded and preserved in a more or less permanent form.

Given the present state of our knowledge about the relationships of different intellectual abilities to the way instructional materials may be designed and produced, it would be presumptuous to do more than point the way toward some tentative generalizations. These are called "statements" in the belief that such a term denotes the provisional quality of the conclusions. Each major statement and sub-statement is derived from an analysis of the research evidence bearing on the issue and a consideration of the theoretical or psychological precepts upon which such a conclusion may be based. Some of the statements are more defensible than others, and the explication of each will attempt to make this clear. In any event, the statements presented here are not given as proven conclusions, but rather as indicators of the direction of the evidence and the statements may be treated as hypotheses subject to the usual verification by further research.

The next section of this paper will present a single statement or group of related statements about the relationships of instructional media design to intellectual abilities, and cites and discusses the supporting research and theory. The following sections draw these statements together into a number of theoretical integrating generalizations and give prescriptions for the design and production of instructional materials or products.

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Statements About Relationships of Instructional Media Design to Intellectual Abilities

Selection of Media Form

What form should the stimulus take in order to benefit individuals of different intellectual abilities? The concern here is with such factors as pictorial vs verbal form, motion vs still presentation, audio vs printed mode, or single- vs multi-channel information transmission. Where appropriate, statements bearing on these variables as they relate to intellectual abilities are presented.

1. There is no apparent support for the supposition that individuals of higher mental ability may learn more from verbal treatments and those of lower ability from pictorial treatments.
   1.1. Individuals of higher mental ability may benefit proportionately more from presentations by perceptually complex, fixed-pace, information-laden, multi-channel motion pictorial forms (motion pictures and television) than will those individuals of lower mental ability.

Following a comprehensive review of the research and consideration of predictions regarding interactions between mental ability factors and the visual vs verbal mode of stimulus presentation, Cronbach and Snow (1973) reported inconclusive results. It is possible to balance off those studies that reveal aptitude-treatment interactions supporting one hypothesis with those supporting the opposite hypothesis or those finding no interaction

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at all. Yet there does appear to be evidence from selected studies reviewed by Cronbach and Snow, as well as research not reported by them, that suggests the existence of factors that could guide the selection of media forms for particular mental ability learner groups.

There is some experimental and theoretical support for the notion that higher ability individuals may profit more than those of lower ability from the more visually complex motion picture as contrasted to verbal presentations. Not only do the highs learn more than the lows,but they learn proportionately more. In an unpublished study by Frederick, Blount and Johnson (1968), reported by Cronbach and Snow (1973), a "figural" programed instruction treatment that employed a tree diagram to organize the symbol notation on structural grammar in teaching eighth graders was best for high ability students and very bad for lows. These extreme differences did not exist for treatments that used either symbolic notation or a verbal treatment without symbols or figures. Gagné and Gropper (1965) compared performance on seven programed instruction lessons on mechanical advantage by eighth graders, presented either with motion picture demonstrations of concepts to be developed or with the use of words only. They found no interaction between the the visual or verbal mode of presentation and verbal ability. However, in an a posteriori analysis of the data, Cronbach and Snow (1973) conclude that the verbal treatment was better for individuals with low scores on two preliminary program lessons (Pre-Achievement), and the visual treatment was comparatively better for those with high Pre-Achievement scores. If the Pre-Achievement scores can be considered to be a measure that involves verbal ability, there would appear to be evidence supporting

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the contention that higher ability learners will profit comparatively more than lows from visual-pictorial presentation modes.

There is other possible supporting evidence for this conclusion. Radlow (1955) made a factor-analytic study of the relationships between certain abilities and factual learning from two sound motion pictures with basic Army trainees. He found that Verbal Comprehension (or test of vocabulary definition), General Reasoning (ability to solve problems), and Spatial Orientation (ability to determine changes in direction and position of an object) from the Guilford-Zimmerman Aptitude Survey were the best predictors of film learning, but that Perceptual Speed (requiring rapid recognition of small changes in detail) was a relatively unimportant predictor. If the factors measured in Verbal Comprehension and General Reasoning are similar to those measured in common mental ability tests, individuals possessing these abilities to a higher degree may benefit the most from motion pictures. In an a posteriori analysis of a series of seven experiments conducted by Allen et al (1970), who tested for the identification of specific physical characteristics or names of things or events presented by pictorial or verbal means, a tendency was found for the higher mental ability individuals to surpass the lows in their gains from the more perceptually rich sound motion pictures than from the verbal non-pictorial treatments. Such differences did not hold for sound-slide presentations, leading to the supposition that the still slide pictures may not have taxed information-processing abilities to the extent done so by the sound motion pictures.

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There was, however, evidence that low ability individuals may profit more than highs from sound motion picture presentations. Gibson (1947) found that low ability Air Force trainees during World War II showed greater improvement than highs from filmed gunnery training than from a printed instructional manual. Koran, Snow and McDonald (1971) studied the relationships of verbal and perceptual aspects of intern teacher aptitude to the video-mediated modeling of teaching procedures vs written modeling as measured by performance and written tests relating to "analytic questioning" of pupils. They found evidence that may support the notion that individuals low in general fluid ability and high in memory for nonverbal details presented in complex moving visual displays will profit more from the videotape portrayal of a teaching skill to be learned than from a written verbatim text from the sound track of the video model. On the other hand, those high in general fluid ability and low in film memory will profit more from the written modeling treatment. It should be pointed out, however, that the authors did conclude that the slowly paced and detailed video-modeling treatment may have compensated for the poorer perceptual processing and analytical abilities of the low ability individuals.

Becker (1974) found both a significant posttest and a retention test superiority for a multi-channel sound-slide treatment over a comparative sound-along treatment for low verbal ability high school English students in the learning of the concept of poetic metaphor. Given the absence of such an effect on the posttest with high ability learners and an otherwise consistent high over low superiority with other treatments, it appears that the multi-channel mode had a more facilitative effect upon low verbal ability individuals than upon those of high or medium ability.

It may be seen, therefore, that answers to the question of whether to use pictorial or verbal presentation modes with different ability learners are not easily obtained. But if we make the assumption that low ability individuals are deficient in their perceptual processing and analytical skills, there is some reason to believe that they will be handicapped in their learning from stimuli that require them to use such skills. Such may be the case with sound motion picture films that present

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information-rich visuals at a pace too rapid for mental processing and that are unavailable for review except from the learner's memory store of what he has seen. On the other hand, multi-channel pictorial presentations may contribute to the learning of lower ability individuals if they contain other design features (to be detailed later) that enhance learning by this group or exclude features that might serve to inhibit such learning.

2. The motion pictorial form may be more effective than the still pictorial form at all intellectual ability levels for presenting factual information, models for imitation, and mental processing operations.

   2.1. Individuals of low verbal reasoning ability may benefit more than those of high ability from motion depiction of an action or operation that duplicates the mental processing of that operation.

   2.2. Individuals of higher mental ability may benefit proportionately more than those of low ability from motion depiction of the order of occurence of objects, events, or processes where an ordering task is involved.

There is relatively little research that pertains directly to a comparison of the motion picture presentational mode with still picture presentation, and even less that treats this variable in relation to learner aptitudes. There would appear, however, to be an overriding advantage for the silent motion picture presentation form over the silent still picture, but one that is greatly reduced or eliminated when sound motion or still pictures are compared (Roshal, 1961; Allen and Weintraub, 1968; Allen et al, 1970).

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The most revealing evidence results from two studies conducted by Salomon (1970, 1972a) in which he investigated the effects of a function he calls "supplantation," that is, a process that replaces or supplants a covert mental operation already in the learner's repertoire but which he would have to activate on his own. Exposure to such stimuli is likely to cause him to "imitate, internalize, and use as a generalized schema the process which he oberves." In one study Salomon (1972a) compared treatments that "zoomed" in and out in motion on details in prints of oil paintings, showed slides of the entire pictures, or showed a slide of the entire picture and then individual slides of the details. It was found that low verbal reasoning eighth graders benefited more than those of high ability from the motion picture supplantation, but that the high ability group benefited more from the viewing of a single slide of the picture. In another experiment, Salomon (1972a) compared visualization performance in the laying-out of solid objects and "folding" them back again when presented by motion supplantation and by slide presentation methods. Again, the supplantation, in which the process was shown in motion, was beneficial to the low verbal ability individuals and debilitating to the highs. It would appear that the motion picture was better able to imitate, and thus supplant, the mental operation required of the task, and it may suggest that it compensated for the poorer perceptual processing abilities of the lower ability individuals. The high ability group, on the other hand, was better able to internalize the mental process involved and rely on its own mediators. This group may have found the "zooming-in" motion presentation unnecessary and even interfering with their own processing of the information.

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The Koran, Snow and McDonald (1971) study may present another example of the supplantation function. In this study the video-modeling treatment, which portrayed teaching skills to be learned by means of videotapes, benefited low mental ability individuals. The authors suggested that this method compensated for deficiencies in perceptual coding abilities and analytical skills by providing a "behavioral representation for the learner that he could not generate for himself if given the written-modeling treatment."

In a posteriori analyses of studies by Allen, Filep and Cooney (1967) and Allen, et al (1970), some tendencies were found for high mental ability learners to benefit more than those low in ability from motion picture over still picture modes of presentation in the learning of material of a "concrete" nature such as the identifying of the specific physical characteristics or names of things and events. However, the reverse effect was found by Allen, Filep and Cooney (1967) for content that was "abstract" and which consisted predominantly of verbal concepts for which there were no direct "concrete" referents. In this case, eighth grade students of lower mental ability benefited more than highs from motion picture (as contrasted to still picture) supplantation of verbal programed learning sequences in learning such abstract content as spelling and definitions in crystallography.

Both Salomon (1972a) and Allen and Weintraub (1968) discovered evidence relating to the interaction of mental ability to the task of ordering a sequence of events, procedures or objects. Salomon (1972a), in the "supplantation" study described above, found that the order in which the pictures were presented was also learned. In this case, low verbal

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reasoning subjects manifested less order in scanning posttest stimuli after the supplantation ("zooming-in" on details in pictures) than after the activation (entire picture shown only) treatment. However, the high ability subjects demonstrated more order in scanning details after the supplantation than after the activation treatment. In the Allen and Weintraub (1968) study, the learning of the serial order of occurence of objects, events and procedures in nine separate stimulus presentations by fifth and sixth graders was tested. There was a tendency for the high mental ability individuals to perform proportionately better than those of low ability after exposure to silent motion picture stimuli than to silent slide stimuli of the same processes. Although the low ability individuals performed better after exposure to the silent motion picture than to the still picture stimuli, these differences were not large in most cases, and showed less variability than did the highs. Both of these studies seem to show that the order in which a process, sequence of events or discrete information occurs is best learned by means of motion picture depiction, but that higher mental ability learners will profit from this mode to a greater degree than will those of lower ability.

In considering the possible relationships of mental ability to the motion or still picture form of media presentation, the evidence appears to support the conclusion that the learning of lower mental ability individuals will be enhanced when motion is employed. However, this conclusions is not as clear-cut as we might wish, for this effect may depend upon the nature of the content to be learned and the demands such material puts upon the information-processing abilities of the learner. The Salomon (1972) and

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Koran, Snow and McDonald (1971) studies seem to underline the greater representational capabilities of the motion picture in that it can show, as Salomon has pointed out, the transformations that occur in a process and present a model that the learner can imitate and internalize as a substitute for his own deficient mental processing skills. This may also account for the superiority of the motion picture with low ability subjects in learning abstract content in the Allen, Filep and Cooney (1967) study. The abstract nature of the material to be learned may have put a burden on lower ability individuals that was relieved or compensated for by a presentational technique (i.e., motion picture) which substituted for the mental processing these learners had to activate on their own with still picture stimuli. The higher ability learners, in turn, did not need such mediators. It is unclear, however, why the "concrete" content was learned better through motion picture depiction by the higher ability group unless mental processing assistance was not required in this particular case and other factors contributed to the results. The entire question is indeed an open one, and needs further investigation.

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Arrangement of the Instructional Message

How should the content of the transmitted information or message be organized so as to be most instructionally effective for different mental ability groups? That is, what can the designer and producer do to manipulate, arrange, emphasize, or enhance the way the message is presented so as to optimize learning from it? The emphasis is on such factors as techniques for preparing the learning for the instructional message, the elicitation of response from the learner and giving him feedback and knowledge of results of the correctness of that response, directing and maintaining attention to elements in the message, repetition or redundancy of the message, pacing, questioning, sequencing, structuring the message, and motivating the learner. Not all of these factors are susceptible to analysis for the intellectual abilities domain, but a number of statement may be advanced at this time.

3. Introductory presentations, which provide an organizing structure for the content that follows, may enhance the learning of that material and make it more resistant to forgetting for learners of all levels.

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3.1. Individuals of lower mental ability may benefit more than those of higher ability from exposure to "advance organizers" and other motivating preparatory procedures that establish a set to learn the material to follow.

The general facilitative effect of prior preparation of the learner for the instruction to follow has been well documented (Anderson, 1967; Gagné and Rohwer, 1969) and would seem to apply to learners of all intellectual abilities. However, little research having a direct bearing on the question of possible aptitude-treatment interactions has been conducted.

Ausubel and Fitzgerald (1962), using educational psychology students as subjects, studied the effects of a written "advance organizer" designed to provide ideational anchorage for a written passage on endocrinology of pubescence that followed. They found that lower verbal ability learners retained significantly more of the "organized" material than of the material with no organization, but that there were no differences for the high and middle ability subjects. The authors concluded that the organizers, by providing ideational anchorage, "facilitate the learning and retention of totally unfamiliar material for those subjects who have relatively little verbal ability." Subjects of higher ability are capable of "spontaneously organizing new material around relevant, more inclusive concepts, and hence derive little or no benefit from introduced advance organizers." In a study which combined textual prose advance organizers with review questions in learning of social studies material by ninth graders, Allen (1970) found

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that the specific learning appeared to be more resistant to forgetting for students of average or below IQ than for those above average. However, this effect for the advance organizers was facilitative only for the specific questions and had no general effect. The opposite was true for the higher ability students. The author suggests that the lower ability learners may be inclined to "file" information by means of the more specific question, the advance organizers serving to make the questions more meaningful. The higher ability learners, on the other hand, may have selected the more general advance organizers for integration in their cognitive structure. These are certainly questions that do not permit definitive answers at this time, but do suggest that different media design factors may work in concert to achieve particular ends.

The meager research evidence reported above merely confirms what theoretical considerations seem to suggest. It would appear that some type of organizing procedure or other kinds of preparatory instructions, motivators, outlines, or devices that focus the individual's attention on the communication to follow or assist in structuring it should aid the lower ability student. He is deficient in such attentional and organizational skills, and the organizer should aid in compensating for this lack.

4. The structuring or organizational outlining of the content of an instructional communication may increase the learning of the content for learners of all abilities.

4.1. Organizational outlining or structuring of materials to be learned may benefit the lower mental ability individuals to a greater degree than those of higher ability.

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The imposition of an organizing structural outline on the content to be learned would appear to be generally effective (Anderson, 1967; Tulving, 1968; Gagné, 1973), but the precise ways this structuring may best be accomplished has yet to be established. Comparatively little research attention has been given to the role played by specific headings within the material itself or the use of outlining techniques, but the expectations from theory would support their use.

In a study of factual learning by Navy recruits from motion picture films that had printed titles and sub-titles added to organize the films into sections, Northrop (1952) found such techniques to be effective, but only with those films that were not previously well-organized. The addition of such titles and increase in organization benefited the lower mental ability recruits, but not those of higher ability. Lee (1965), in a comparison of different levels of structuring of prose material for Navy officer candidates, found strong evidence favoring a high level of structure which included an introductory outlining paragraph, a final paragraph of summary and conclusions, main and sub-headings within the body of material, and transitional summarizing paragraphs. However, no interaction with verbal aptitude scores were found. Niedermeyer et al (1969) and Brown (1970) both found evidence that lower ability learners were more adversely affected by unstructured or "scrambled" programed sequences in mathematics than were those of higher ability.

It would appear, therefore, that although little direct evidence exists to support the view that outlining benefits lower ability learners, theoretical considerations would suggest its validity. The organizational aids inherent in outlining, structuring, and headings are compensators for the low ability student, who is deficient in organizational skills. On the other hand, the high ability learner can better associate, mediate, and organize stimuli that he encounters.

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5. Directing attention to relevant cues which emphasize material to be learned within an instructional communication may increase the learning of that material for all ability groups.

5.1. Individuals of lower mental ability may benefit more than those of higher ability from attention-directing procedures.

The directing of the learner's attention and the maintenance of that attention during exposure to instructional media may be accomplished by the employment of a number of techniques: using visual pointers or colors, giving verbal directions in the narration, using novelty and change in the stimuli, underlining or accenting crucial cues, emphasizing, and many others. Gagné and Rohwer (1969) found such procedures to be generally facilitative to learning, and May (1965) reviewed a body of literature and drew the same conclusions.

In a more directed consideration of the interactions between these techniques and the mental abilities of learners, Snow and Salomon (1968) pointed out that the "more rigorously organized and attention-focusing character" of sound pictorial media might be more advantageous for both lower and higher mental ability learners. The lows need the organized, redundant, attention-directing, and easily discriminable pictorial presentation and the highs need the greater information-carrying capacity of this mode. They suggest an "attentional hypothesis" based on Zeaman and House's (1967) research on discrimination learning with retardates and Kanner and Rosenstein's (1960) Army television study in which low ability

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trainees learned more from color television and highs from black and white. Although this hypothesis postulates equal weight to high and low mental ability groups and poorer performance for those in the middle ability group. there is evidence that the low ability learners are the ones who will profit the most from attention-directing techniques. Salomon (1972b) put forth a suggestion by Cronbach and Snow to the effect that "treatments which force subjects to pay attention to and differentiate among details benefit low general-ability subjects...such treatments compensate for the subjects' deficient attentional and discrimination skills." These same characteristics would handicap learning by high ability subjects, however, because of the unnecessary emphasis on details. Thus, the attention-directing procedures would assist the lower ability learners to do what they cannot do for themselves.

Other studies support this conclusion. Lumsdaine, Sulzer and Kopstein (1961) found that low mental ability Air Force trainees profited more than highs in learning to read micrometer settings from animated films that used such attention-directing devices as arrows and pop-in labels. Allen, Cooney and Weintraub (1968) found some indications that sound track narration directing attention to or pointing out relevant cues to sixth greaders in motion pictures and slide visuals on ecology benefited lower ability and handicapped higher ability learners. Allen, Filep and Cooney (1967) came to similar conclusions, a directive mode of narration being more beneficial to low mental ability groups.

It would appear, therefore, that both empirical evidence and theory point to greater benefit for lower ability learners from procedures that

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give direction to their inspectional behavior of the instructional stimuli to which they are exposed. Such techniques would be expected to compensate for their poorer attentional and discriminational abilities. On the other hand, higher ability learners, because of their ability rapidly to process information, make relationships, and extract symbolic meanings from the stimuli, might be handicapped by the detailed and obvious (to them) emphasizing procedures.

6. The elicitation of an active response or engagement of the learner in active participation during the presentation of instructional material may increase the learning of that material by all ability groups.

   6.1. Individuals of lower mental ability may benefit more than those of higher ability from active participation and response during instructional materials presentation.

There is considerable support for the belief that active participation and response during learning will increase the level of that learning. This phenomenon serves as one of the psychological foundations for programed instruction. Review of the research by Lumdaine (1961, 1963), Anderson (1967), Gagne and Rohwer (1969), and Tobias (1973) underline the importance of this variable in learning from mediated instruction.

There is further evidence that this procedure will benefit the lower mental ability learners proportionately more than it will the highs. Hovland, Lumsdaine and Sheffield (1949) found that low ability Army Signal Corps trainees profited more than high ability trainees from a sound

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filmstrip on the phonetic alphabet and pronunciation of numerals that required audience participation. They also concluded that the participation treatment was increasingly more beneficial to the lows when their motivation was lower and the difficulty of the material was greater. Hamilton (1965) found a tendency for low ability eighth graders to benefit more from a self-teaching program on communism than from reading textual material, but a reverse effect for the high ability students.

However, some contradictory evidence was reported. Gropper and Lumsdaine (1961), in a series of studies on the use of student response to improve televised instruction, found that high ability eighth graders tended to profit more from programed lessons than did those of low ability. But they attributed such differences to the high difficulty level and fixed-pace mode of the lessons. Michael and Maccoby (1961) studied the acquisition of verbal facts from films on civilian defense by high school juniors and seniors under either participation (answer sheet responses) or no-participation conditions. No mental ability by treatment interactions were found under either overt or covert response conditions or on items practiced or not practiced in the participation groups.

Although the evidence supporting an advantage for lower mental ability individuals when responses are elicited during the course of the instruction is not definitive, theoretical considerations would bolster this view. The attention-directing and facilitating qualities inherent in the process of making an active response would seem to compensate for this group's deficient information-processing and attentional skills.

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7. Posing questions related to the material to be learned may increase the learning of that material by all mental ability groups.

7.1. Individuals of lower mental ability may benefit more than those of higher ability from question-posing techniques.

There is a considerable body of research verifying the value of posing or inserting questions into instructional material. Lumsdaine (1963) reviewed this research as it applied to question-posing techniques into instructional films, and Rothkopf (1970) and Frase (1970) have done so for the extensive research they have conducted on the role of inserted questions in printed textual material.

There is less evidence with regard to the relationship of this variable to the mental ability of the learners, but its close affinity to both the attention-directing and response-elicitation processes suggests that the technique calls upon similar mental processing mechanisms and should enhance information acquisition by lower mental ability learners. The higher ability individuals would not appear to need such assistance. As reported above, Allen (1970) found that a combination of review questions with preparatory advance organizers made ninth graders' learning of social studies material more resistant to forgetting for students of average or below IQ than for those above. Shavelson et al (1972) varied the position (before or after) and type (lower order or higher order) of questions and reported that college students with low vocabulary scores retained more when higher order questions were placed after a prose passage. High vocabulary scoring students performed best without questions. No aptitude-treatment interactions were found. Berliner and Cahen (1972) reported other studies that gave support to an aptitude-interaction favoring the use of questions for low mental ability individuals.

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8. The furnishing of correcting or confirming feedback relative to an individual's response during presentation of instructional material may increase the learning of that material for all mental ability groups.

   8.1. Individuals of lower mental ability may benefit more than those of higher ability from feedback and knowledge of results of the correctness of response to presented material.

The evidence supporting the use of correcting or confirming feedback or knowledge of results relative to a learner's elicited response has been extensively reported (Lumsdaine, 1963; Anderson, 1967; Gagné and Rohwer, 1969; Tobias, 1973), and its overall effectiveness confirmed. There is, however, little direct evidence to support an advantage for lower ability students, but the expectations from theory are that such would be the case. Given the poorer attentional and information-processing skills of this group, the facilitating, correcting, and reviewing functions served by such procedures would appear to be more beneficial to the lower than to the higher ability learners.

9. Redundancy of information by means of repetition may increase the learning of that information by individuals at all mental ability levels.

   9.1. Individuals of higher mental ability may be able to profit more than those of lower ability from the repetition.

   9.2. The higher mental ability individuals may be able to profit increasingly more the greater the difficulty of the material to be learned.

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9.3, Lack of redundancy, or removal of details by compression and simplification, may deter the learning of lower mental ability learners.

Repetition of information, or practice, in either an identical or varied form, has been demonstrated to be a powerful contributor to increased learning (Lumsdaine, 1963; Ausubel, 1968; Gagné, 1970), and the application of the principle in practice has been widely studied.

There is less evidence, however, pertaining to the ways this variable might interact with the mental abilities of learners. The a priori expectation might be that lower ability learners would profit most from such design techniques built into instructional materials. Such a view, however, has not been supported by the research evidence. Lumsdaine, Sulzer and Kopstein (1961) found that the more intelligent Air Force trainees benefited more from added examples to a film on teaching the reading of a micrometer, and the advantage to them increased as the material became more difficult. Allen, Weintraub and Cooney (1968) found a tendency for high non-language IQ sixth graders to gain proportionately more than the low ability students from the viewing of a highly redundant factual information film on ecology of the sea. Kanner and McClure (1961), using similar films to those used by Lumsdaine, Sulzer and Kopstein found no interaction of mental ability with either identical or varied repetition on an immediate posttest, but did find a difference in favor of varied repetition for the high mental ability subjects one week after exposure to the stimuli. On the other hand, a study by Michael and Maccoby (1961), in which high school juniors and seniors learned verbal information from a civilian

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defense film, indicated no interaction of ability level to items that had been practiced during participation when the film was shown and those items that had not been practiced.

A study by Kropp, Nelson and King (1967), as reported by Cronbach and Snow (1973), compared sixth grade learning of a textbook statement on a scientific topic with a version that was compressed nearly 20% by removing details and simplifying the content, but not by elucidating the content. The higher ability subjects performed better than the lows, particularly on the simplified version, suggesting that the failure to provide redundancy by removing details, simplifying, and shortening a presentation will work to the detriment of the low ability students and benefit the highs.

Considering the somewhat scanty evidence, it would seem that there might be an optimum level of redundancy for low ability learners. No redundancy in the communication will penalize them by placing demands on their information-processing capabilities, and an excessive amount of repetition may cause boredom and lack of interest. The high ability learner, though, will be able to process compressed material at a fast pace and will have the attentional ability to take advantage of repeated examples and information in cases where he yet needs the information to complete his understanding.

10. Low mental ability individuals may be handicapped in learning from a rapidly paced presentation to a greater degree than those of high ability.

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There is some evidence to support the conclusion that the rate of development or pace at which material is presented to learners will have a relationship to the mental ability level or mental processing capabilities of such learners. The optimum rate of presentation for different types of learners, however, has not been fully determined. It is to be expected that higher mental ability individuals should be able to process the stimulus information more rapidly and efficiently, thus making the faster-paced material the prefered mode for them and the slower-paced material more boring and restrictive. On the other hand, the lower ability individuals may be deficient in information-processing skills and would require more slowly paced stimuli so as to compensate for these deficiencies, the rapidly paced material being inadequately processed. There is some supporting experimental evidence for these conclusions.

Gropper and Kress (1965), reporting on a programed instruction study with eighth graders using differentially paced slide materials, found that the faster the tempo or pacing of the presentation, the wider the gap in performance became between high and low mental ability learners, the faster tempos handicapping the lows. In the Gropper and Lumsdaine (1961) study reported above, the poor performance of low ability individuals on programed lessons over television was attributed in part to the fixed-pace of presentations having a high difficulty level. Eckhardt (1970) studied the effects of the time compression of narration and pictorials upon the learning of traffic safety by the Air Force inductees in a programed lesson. He found that the material could be compressed, or shortened, up to 40% of the time of a normal rate without affecting the learning of higher ability trainees. But the learning of lower ability trainees was significantly impaired by as must as a 25% compression of the material. Wolf (1971) indicated that if scenes do not last long enough on a television screen, low mental ability individuals will not have enough time to assimilate the information.

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Generalizations About Relationships of Instructional Media Design to Intellectual Abilities

Given the set of statements and the supporting research and theory upon which they are based, it is possible to make a number of generalizations about the interactions between the mental abilities of different learners and the different ways instructional media may be designed and presented.

1. Individuals of Low mental ability appear to benefit from instructional procedures that:
   - 1.1. Supplant or replace covert mental operations which the learner would normally need to activate on his own, possibly through the use of motion.
   - 1.2. Arouse, motivate or prepare the learner for the instructional material that is to follow.
   - 1.3. Organize, outline or structure the content to be learned.
   - 1.4. Direct attention to, point out or emphasize content of the stimulus that the learner needs to attend to.
   - 1.5. Elicit an active response from the learner to the content of the communication.
   - 1.6. Feedback to the learner knowledge of the correctness of responses he may have made.
   - 1.7. Raise questions relative to the content of the communication.
   - 1.8. Present the content to be learned at a pace slow enough for mental processing of the transmitted information.

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2. Individuals of Low mental ability appear to be deterred in their learning by instructional procedures that:

2.1. Contain amounts of information, both visual and verbal, that exceed the information-processing capabilities of the learner.

2.2. Contain content that has no inherent organizational structure.

2.3. Contain content that is compressed, shortened or simplified so as to remove all redundancy and details.

2.4. Contain excessive repetition which may lead to boredom and fatigue.

2.5. Contain content that develops at a rate of speed too rapid for adequate mental processing of the information transmitted.

The above generalizations are derived from the research and theory presented and discussed in the first section. As was pointed out in the introduction, such generalizations must be considered as tentative and need to be verified or refuted through future systematic research. However, a careful review of the list will reveal a consistency of findings based on a common theoretical foundation.

It seems clear that those instructional procedures that benefit low ability learners are largely serving a compensatory function. That is, they "provide the learners with the necessary mediators, organization of materials, modality and the like, which they cannot provide for themselves; or circumvent debilitating effects of certain psychological traits or states." (Salomon, 1972) They utilize a number of psychological principles to do this, but the end result of the procedures that are most efficaciously employed is that of compensating for attentional, discriminational, analytical

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and mental processing deficiencies within the low ability learner. Deterrents to the learning by this group would seem, in large part, to be a disregard of these mental deficiencies and the presentation of instructional stimuli that place demands on their intellectual capabilities that are difficult or impossible for them to meet.

3. Individuals of High mental ability appear to benefit from instructional procedures that:

   3.1. Are perceptually rich in information, concepts and sensory images.

   3.2. Place a requirement on learners to organize, hypothesize, abstract and manipulate symbolic meaning.

   3.3. Employ a rapid rate of development of the material, thus challenging their mental processing capabilities.

The generalizations stated above are derived from the research and theory presented in the first section. Whereas the compensatory function was served by instructional procedures for the low ability learners, the preferential function appears to prevail in instructional

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treatments for those of high mental ability. Salomon (1972) states that such treatments "call upon and utilize learners' higher aptitudes, neither making up for deficiencies nor compensating for them." The superior attentional, discriminational, analytical and mental processing skills of this group would seem to demand instructional procedures that utilize such innate abilities. Being able to organize, abstract and process information at a rapid rate, they prefer instructional stimuli presented in this way. And they lose interest in and are bored by material that does not possess these characteristics.

4. Individuals of Middle mental ability would appear to benefit from instructional procedures that:
   - 4.1. Allow the necessary time needed for the mental processing of the transmitted information.
   - 4.2. Supplant or replace covert mental operations which the learner would normally need to activate on his own, possibly through the use of motion.
   - 4.3. Arouse, motivate or prepare the learner for the instructional material that is to follow.
   - 4.4. Organize, outline or structure the content to be learner.
   - 4.5. Direct attention to, point out or emphasize content of the stimulus that the learner needs to attend to.
   - 4.6. Elicit and active response from the learner to the content of the communication.

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4.7. Feedback to the learner knowledge of the correctness of responses he may have made.

4.8. Raise questions relative to the content of the communication.

4.9. Present the content at a pace appropriate to the mental processing capabilities of the learners.

6. Individuals of Middle mental ability appear to be deterred in their learning by instructional procedures that:

6.1. Contain excessively heavy amounts of information exceeding the information-processing capabilities of the learners.

6.2. Contain content that has no inherent organizational structure.

6.3. Develop at a rate of speed too rapid for adequate mental processing of the transmitted information.

The generalizations derived for those learners in the middle mental ability range bear a close similarity to those for low ability learners. They are, in fact, based on more general research findings and theory and not specifically on discrete experimental evidence with individuals as distinghuished from highs and lows in this middle ability group. Very little research with such subjects has been conducted. We do not know whether the optimum instructional procedures to be employed for this group serve either a compensatory or a preferential function, depending upon the nature of the instructional task, or whether they may serve neither or both. One is tempted to speculate that this group falls somewhere between the two extremes, and thus may require both kinds of instruction depending upon the prevailing conditions. However, this is an open question.

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Prescriptions for Instructional Media Design

The 23 statements and the generalizations presented in the first two sections of this paper describe the nature of the relationships of instructional media design to intellectual abilities. This section will present more specific instructional prescriptions for applying these conclusions to the actual design and production of instructional materials for the low and high mental ability groups. It should be apparent that all of these prescriptions would not be employed in the preparation of any single instructional communication; and, given the present state-of-the-art, it becomes a matter of designer-producer judgment as to just what procedures would be appropriate given the nature of the content being taught, the instructional objectives being met, and other instructional conditions prevailing in the utilization situation. These prescriptions are not exhaustive, but are intended to suggest useful lines of application for the different instructional media design factors.

1. Instructional material designed for learners of Low mental ability should employ the following design techniques:
   - 1.1. Preparatory or motivational procedures that establish a set to learn the material to follow (at the beginning and at points within the communication), such as:
     - 1.1.1. Advance organizers that provide organizing elements from previous material to which the new material may be related.

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1.1.2. Verbal or pictorial overviews, outlines or summaries of material to follow.

1.1.3. Verbal direction to "attend to..." or "learn from..." specific parts of the content.

1.1.4. Points to look for, questions to answer, or problems to solve.

1.1.5. Kinds of activities to engage in or procedures to follow.

1.2. Organizational outlines or internal structuring of the content, such as:

1.2.1. Printed or spoken headings or sub-headings of major divisions of the content.

1.2.2. Enumeration of points as presented (e.g., "first," "second," etc.).

1.2.3. Logical ordering and sequencing of the content.

1.3. Attention-directing devices that point out, emphasize or direct attention to relevant cues in the communication, such as:

1.3.1. Verbal directions to "look at," "find," "see," etc. in conti guity with visuals.

1.3.2. Visual pointers (pop-in labels, arrows, circling, alternating or flashing emphasizers, etc.).

1.3.3. Underlining, full capitalization or italicizing of printed material.

1.3.4. Use of color for emphasis.

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1.3.5. Progressive build-up or disclosure, or disassembly or reassembly ("implosion") of pictorial elements.

1.3.6. Animated or cartoon-type visuals that reduce detail to relevant cues inherent in the material to be learned.

1.3.7. Close-ups, large pictures, large type.

1.3.8. Movement and change.

1.3.9. Emphatic repetition of elements to be perceived.

1.4. Procedures that elicit active participation and response from the learner to the content of the communication, such as:

1.4.1. Overt "speaking-out" or written responses to built-in request for response in audio, pictorial or printed presentations.

1.4.2. Covert "thinking" responses to built-in requests for response in audio, pictorial or printed presentations.

1.4.3. Insertion of questions in printed or audio form, to which answers (either overt or covert) are required.

1.4.4. Note-taking when enough time is provided within the presentation to permit it.

1.4.5. Stopping the film or presentation for student reponse or discussion as a result of built-in instructions.

1.5. Provision for correcting or confirming feedback to responses elicited from learners, such as:

1.5.1. Printed or spoken answers to elicited responses.

1.5.2. Pictorial depiction of answers to elicited response.

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1.5.3. Correctness of response confirmed ("right" or "wrong") where means exist for interaction (as in computer-assisted instruction).

1.6. A slow rate of development or pace of presentation of the content to be learned, such as:

1.6.1. Narration, in audio recordings or pictorial accompaniments, that is presented at a moderate rate of speed.

1.6.2. Development of concepts and ideas in pictorial material at a fixed and easily comprehensible rate of speed.

1.6.3. Scenes, in visuals, of sufficient length to permit adequate time for mental processing.

1.7. Formats that provide for supplantation or replacement of the mental processing operations, normally done by the learners, by means of imitation or modeling, such as:

1.7.1. Filmic techniques that "zoom" in and out on details, duplicating (and thus supplanting) perceptual and mental processing operations.

1.7.2. Filmic or progressive graphic development of a process or operation in the sequential order of occurence.

1.7.3. Movements that depict the continuous transformations from one state of being to another state.

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2. Instructional material designed for learners of High mental ability should employ the following design techniques:

2.1. Higher information density, pictorial and conceptual complexity and richness in images, ideas and relationships, such as:

2.1.1. Multi-image, multi-screen or montage.

2.1.2. High speed of presentation within screen or units of the message, resulting in higher amounts of factual and conceptual information presented per unit of time.

2.1.3. Combination of pictorial and narration in a non-redundant relationship.

2.1.4. Rapidly changing pictorial stimuli.

2.1.5. In print, longer and more complex sentences.

2.2. Rapid rate of development of information and concepts being communicated, such as:

2.2.1. More rapid pacing and rate of development of audio materials and narration to pictorial materials

2.2.2. A fast rate of development of information and ideas with a minimum of detailed explanations.

2.3. A format that places requirements on the learner to organize, hypothesize, abstract and manipulate the stimuli mentally in order to extract meaning from it, such as:

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2.3.1. Complex stimuli (pictorial and verbal to which learner is directed with instructions to engage in a particular way.

2.3.2. Examples of concepts, ideas or facts from which inferences may be drawn as a result of mental processing.

It is clear, from a study of the above prescriptions, that it is much easier to specify those design techniques that will compensate for mental processing deficiencies in lower ability learners than satisfy the preferential ways of learning of those of higher mental ability. It may well be the case that high ability learners may profit to some extent, depending upon conditions, from an application of the design techniques that are absolutely essential in the preparation of instructional materials for the low ability students. With this higher group, it may be a matter of the degree to which such techniques as attention-directing, elicitation of response, structuring and pacing are employed rather than their complete absence. The general research does, in fact, show that they do profit from such instructional methods. On the other hand, the lower ability group may have their learning seriously impaired by the employment of techniques that assist the highs. In this case, the complex, information-rich rapidly paced material may act as a learning deterrent.

The question may then be posed relative to prescriptions of media designed for learners in the large middle group of mental ability. In all probability, the media design techniques used with low ability learners will prevail for the middle group as well, but perhaps with a reduced

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influence. The great body of research done on media design factors probably pertains to this middle ability group, and it points clearly to the efficacy of use of such instructional procedures as eliciting student participation and response, furnishing of feedback and knowledge of results, directing of attention to relevant cues essential to learning, and using repetition and redundancy in the presentation of material to be learned. These are all factors that assist low ability learners. Therefore, we might conclude that similar techniques of design would benefit either group, but with some differences in degree to which certain techniques may exert their effects.

A Summing-Up

There is no easy answer to the problem of selecting the optimum presentational mode for a particular ability group. This fact is brought out clearly by the Koran, Snow and McDonald (1971) study. Here the complexity and visual richness of the video-modeling (filmic) treatment, which might be expected to favor the higher perceptual-analytic individuals, in fact favored the lower ability group, possibly because it compensated for their deficiences in perceptual processing and analytical skills. It did this by providing an explicit and detailed concrete presentation of the content at a pace slow enough to permit them to process the information. Thus, one design technique may override the effects of another, and it is the designer's task to weigh their relative effects. The opposite effect may have occured in the Gropper and Lumsdaine (1961) study, where there was an expectation for higher learning by low ability learners from response-eliciting stimuli, but the high difficulty level and rapid fixed-pace of

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the presentation resulted in better gains for the high ability learners. Then, too, different design techniques may exert their effects when they work in combination with other techniques. The Allen (1970) study is an example of advance organizers working together with the posing of questions to produce a particular influence on learning by different ability groups that did not occur when either technique was used alone. Thus, the production of effective communications may still be largely an art, but hopefully an art that utilizes established principles of how individuals learn and what means may be taken to enhance that learning.

Although the results and generalizations presented in this paper are tentative at best, they are in general accord. There seems to be a consistency of findings that point logically to one kind of media design approach for one class of learners and another for the opposite class, with a substantial area of overlap shared by both. No claim of finality is made here for the conclusions that have been drawn, only that they present a reasonable and empirically based model for the design of instructional media for learners of different mental abilities. Hopefully they may be tested further for their appropriateness and modified or expanded through the experience that is gained from such evaluation and use.

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